Globular Cluster Halos around the brightest Fornax Ellipticals

Markus Kissler-Patig

UCO/Lick Observatory, University of California, Santa Cruz, CA 96054, USA

1. What it is all about

Our goal is to understand the globular clusters surrounding the brightest galaxies in the Fornax galaxy cluster, and relate their properties to the formation history of the galaxies and the galaxy cluster. In general, we need to understand the presence of globular cluster sub–populations around the brightest galaxies (and their apparent absence around the less luminous ellipticals, Kissler-Patig 1997). In particular, the extreme over–abundance of globular clusters around the central cD galaxy is still unexplained.

Fornax is a relatively poor galaxy cluster at a distance of $\simeq$ 19 Mpc (assumed throughout the following). The properties of the brightest early–type galaxies (taken from the RC3, Kissler-Patig et al. 1997a,b, and Forbes et al. 1997) are summarized below, including the number of globular clusters (N_{GC}), and the specific frequency (S_N). NGC 1399, a giant cD galaxy, sits in the center of the cluster gravitational potential, while NGC 1404 and NGC 1380 are at projected distances of 50 kpc and 200 kpc to the SE and NW respectively.

Name	M_{V_T}[mag]	B−V [mag]	Vel_{opt} [km s^{-1}]	N_{GC}	S_N
NGC 1399	−21.8	0.96	1447	$\simeq$ 6000	$\simeq$ 11
NGC 1380	−21.5	0.94	1841	$\simeq$ 600	$\simeq$ 2
NGC 1404	−21.4	0.97	1929	$\simeq$ 750	$\simeq$ 2

2. The globular cluster systems of NGC 1399, NGC 1380, and NGC 1404

• Qualitatively, NGC 1399, NGC 1380 and NGC 1404 have very similar globular cluster populations (Kissler-Patig et al. 1997a,b, Forbes et al. 1997). All have bi–modal globular cluster color distributions and have about the same number of red and blue globular clusters. The properties of these sub–populations were investigated spectroscopically in NGC 1399 (Kissler-Patig et al. 1998a), with extremely deep 3–color photometry in NGC 1380 (Kissler-Patig et al. 1997b) and with 2–color HST photometry in NGC 1404 (Forbes et al. 1997). The blue globular clusters show very similar properties to the Milky Way halo globular clusters (similar age and metallicity, spherically distributed and extended), and could constitute a *halo*. On the other hand, the red globular clusters are more metal rich (comparable to, maybe slightly richer than, the Milky Way disk/bulge globular clusters). There is some evidence that the latter could be a few gigayears younger than the former, but both sub–populations are old,

and did *not* form in a late ($z < 1$) merger. This is not really surprising since hierachical clustering models predict (e.g. Kauffmann 1996) and stellar populations indicate (e.g. Bender 1997), that these galaxies formed at higher redshifts. However, both NGC 1399 and probably NGC 1380 have a small number of *very red* globular clusters, that could be the product of a more recent interaction. Unfortunatly, both stellar population synthesis models and observations are not yet accurate enough to pin down their ages with any certainty.

• Quantitatively, the globular clusters in NGC 1399, NGC 1380 and NGC 1404 differ dramatically. NGC 1399 is only 0.3 magnitudes brighter than NGC 1380, and only 0.4 mag brighter than NGC 1404. However, NGC 1399 hosts $\simeq 6000$ globular clusters (Kissler-Patig et al. 1997a, Forbes et al. 1997), while NGC 1380 hosts only $\simeq 600$ (Kissler-Patig et al. 1997b) and NGC 1404 $\simeq 750$ (Forbes et al. 1997, Richtler et al. 1992). In terms of specific frequency, NGC 1399 has a $S_N \simeq 11$, while both NGC 1380 and NGC 1404 have $S_N \simeq 2$. The typical value (with little scatter) for the low-luminosity early–type galaxies (NGC 1374, NGC 1379, NGC 1387, NGC 1427) is $S_N \simeq 3$ (Kissler-Patig et al. 1997a). *The globular clusters around NGC 1399 are not different from the ones around NGC 1380 and NGC 1404, but are more numerous by about a factor of 10.*

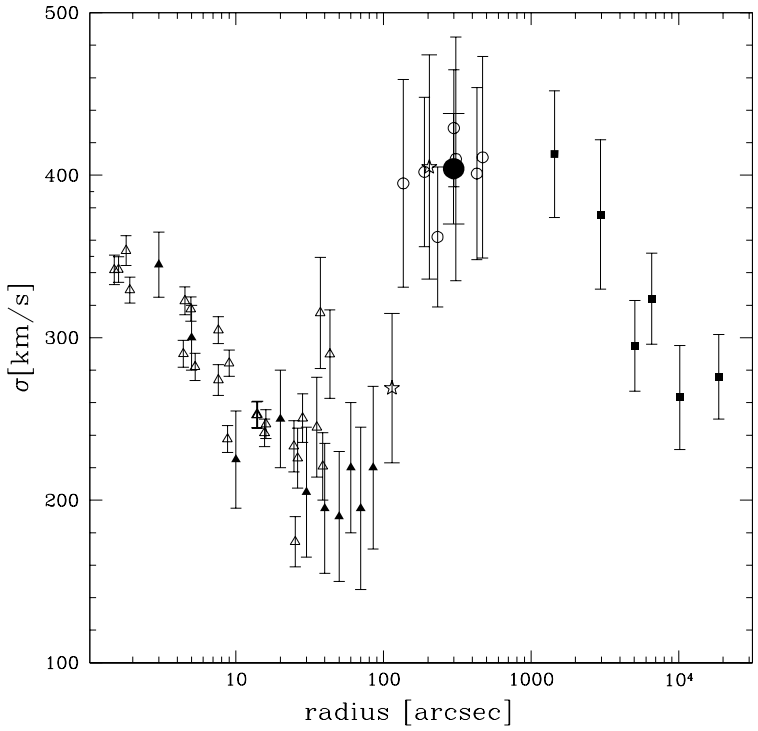
3. Kinematics in NGC 1399 and Fornax

A sample of 76 radial velocities for globular clusters around NGC 1399 was compiled from (Grillmair et al. 1994, Minniti et al. 1998, Kissler-Patig et al. 1998a). We found no significant correlation of velocity or velocity dispersion of the globular clusters with position, position angle, color, or radius, either in the whole sample or in any sub–sample. In particular, we could not find any rotation, nor are the "high velocity" clusters clearly associated with either NGC 1380 or NGC 1404 (see Kissler-Patig et al. 1998b for the detailed analysis).

However, the velocity dispersion of the globular clusters (and any sub–sample!) is high (400 ± 40 km s^{-1}). The figure below shows the velocity dispersion of several components: triangles show the velocity dispersion of the stars around NGC 1399 (Franx et al. 1989, Bicknell et al. 1989), stars mark the velocity dispersion of the planetary nebulae (Arnaboldi et al. 1994), squares show the velocity dispersion of the cluster galaxies (Den Hartog & Katgert 1996, Ferguson 1989), and circles show the velocity of the globular clusters (solid) and various globular cluster sub–samples (open, see Kissler-Patig et al. 1998b for a detailed description). The globular clusters have a velocity dispersion that contrasts with that of the stellar component of NGC 1399, and seems rather similar to that of the cluster galaxies. *The globular clusters appear to feel the cluster potential, rather than the potential of NGC 1399* (as already noticed by Grillmair et al. 1994).

4. Connecting the pieces of the puzzle

The globular cluster system of NGC 1399 does not differ qualitatively from the systems of NGC 1380 and NGC 1404, the second and third brightest galaxies in Fornax, but hosts about 10 times more clusters. *The same mechanisms seem to*



be at the origin of the globular clusters around all three galaxies. The only clear difference between NGC 1399 and the two other galaxies, is its position in the very center of the galaxy cluster. The over–abundance of globular clusters seem therefore to be linked to the preferential position. Furthermore, the kinematics of the globular clusters differ from those of the stellar component, but ressemble those of the cluster galaxies. *A large fraction of the globular clusters seen around NGC 1399 seem to be associated with the galaxy cluster, rather then with the galaxy itself.*

There are two possible explanation for the presence of the globular clusters in the center of the galaxy cluster: *a)* They might have formed in the center of the galaxy cluster (e.g. Balkeslee 1996), *b)* they might have been accreted/stripped from the other cluster galaxies (Muzzio 1987, White 1987). At this point, we cannot clearly distinguish between the two scenarios. But we note that there is approximately the same number of blue and red globular clusters around NGC 1399. If the red (disk/bulge like) clusters are associated with the formation of the stellar component, and thus their number expected to scale with the galaxy size, then the excess of red clusters around NGC 1399 is too large to be explained by formation in situ, and *stripping/harrassement must have played a role.* Stripping is further supported by the similarity of the globular clusters around the three galaxies. If stripping was the dominant process, we expect "tails" of globular clusters towards the other galaxies. These tails should be detectable in large photometric and spectroscopic studies.

Acknowledgments. It is a pleasure to thank J.P.Brodie, M.Della Valle, D.A.Forbes, P.Goudfooij, C.J.Grillmair, M.Hilker, J.P.Huchra, L.Infante, S.Kohle, G.Meylan, D.Minniti, H.Quintana, T.Richtler, L.L.Schroder, J.Storm, who collaborated on the various parts of this work.

References

Arnaboldi, M., Freeman, K.C., Hui, X., Capaccioli, M. & Ford, H. 1994, ESO Messenger, 76, 40

Bender R., 1997, in "The Nature of Elliptical Galaxies", ASPCS Vol.116, eds. M.Arnaboldi, G.S.Da Costa, P.Saha, p.11

Bicknell, G.V., Carter, D., Killeen, N., Bruce, T. 1989, ApJ, 336, 639

Blakeslee J.S., 1996 PhD thesis, Massachusetts Institute of Technology

Den Hartog, R. & Katgert, P. 1996, MNRAS, 279, 349

Ferguson, H.C., 1989, AJ, 98, 367

Forbes, D.A., Grillmair, C.J., Williger, G.M., et al. 1997, MNRAS, in press

Franx, M., Illingworth, G. & Heckman, T. 1989, ApJ, 344, 613

Grillmair, C.J., Freeman, K.C., Bicknell, G.V., et al., 1994, ApJ, 422, L9

Kauffmann G., 1996, MNRAS 281, 487

Kissler-Patig, M. 1997, A&A 319, 83

Kissler-Patig, M., Kohle, S., Hilker, M., et al. 1997a, A&A 319, 470

Kissler-Patig, M., Richtler, T., Storm, J., Della Valle, M. 1997b, A&A, in press

Kissler-Patig, M., Brodie, J.P., Schroder, L.L., et al. 1998a, AJ January issue

Kissler-Patig M., et al., 1998b, AJ in preparation

Minniti, D., Kissler-Patig, M., Goudfrooij, P., Meylan, G. 1998, AJ January issue

Muzzio, J.C. 1987, PASP, 99, 245

Richtler T., Grebel E.K., Domgörgen H., Hilker M., Kissler M., 1992, A&A, 264, 25

White R.E. III, 1987, MNRAS, 227, 185